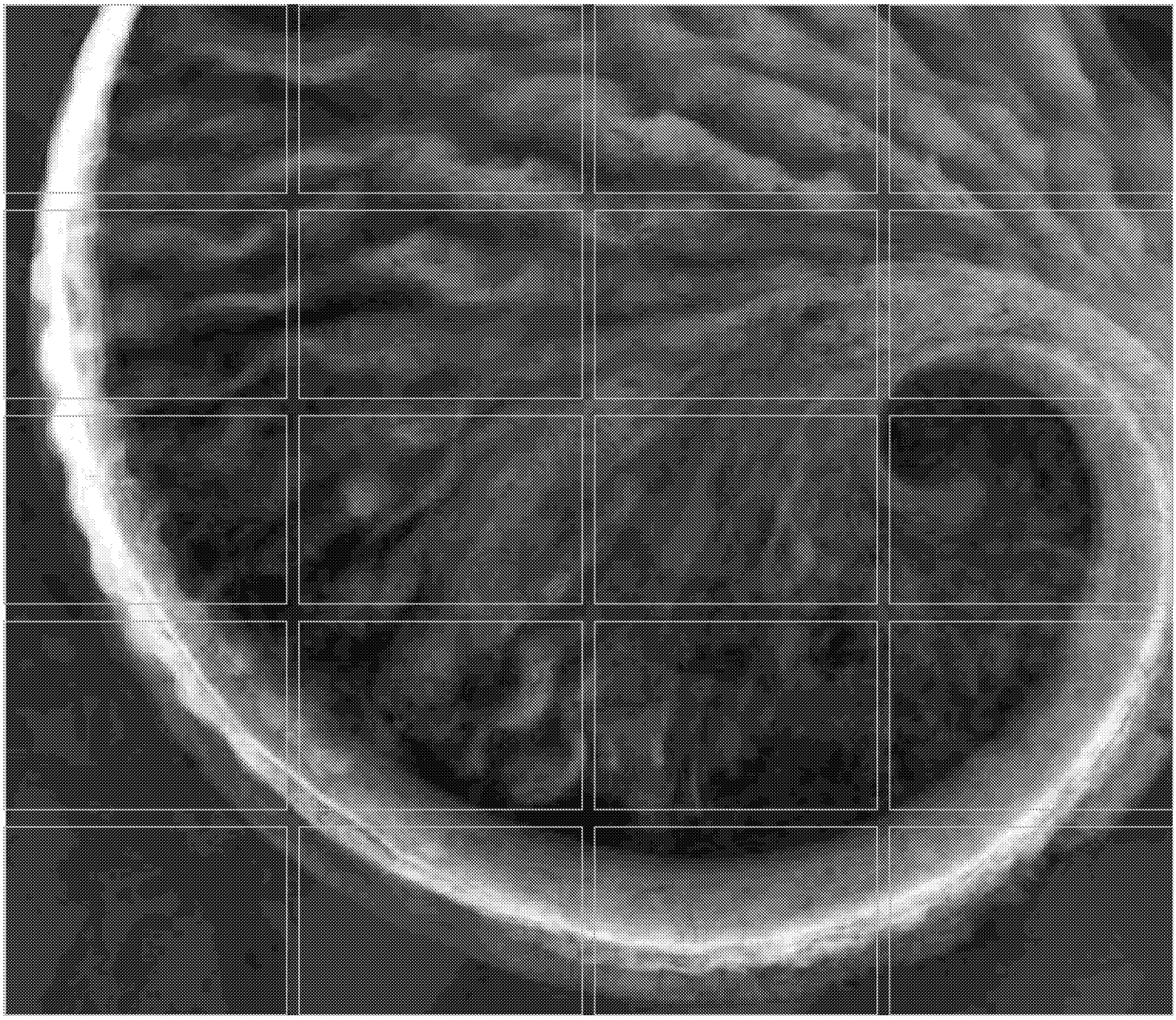

Modeling Report: HFPO-DA Atmospheric Deposition and Screening Groundwater Effects

Prepared for:
The Chemours Company

Fayetteville Works Facility
Fayetteville, North Carolina

April 27, 2018
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The Chemours Company

Modeling Report: HFPO-DA Atmospheric Deposition and Screening Groundwater Effects

April 27, 2018

Project No. 0422611
Fayetteville Works Facility
Fayetteville, North Carolina

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EXECUTIVE SUMMARY

The Chemours Company (Chemours) has requested that Environmental Resources Management (ERM) conduct air quality modeling to predict potential impacts of emissions of Hexafluoropropylene Oxide – Dimer Acid (HFPO-DA, or GenX), from sources at the Chemours Fayetteville Works in Bladen County, North Carolina. ERM has completed a deposition modeling analysis for emissions of HFPO-DA into ambient air, and has completed a preliminary screening assessment of the effect of those emissions on concentrations in groundwater. The modeling and analysis was performed for a base case emissions scenario and for three emissions control scenarios expected to be completed in the May 2018, October 2018, and 2019-2020 time frames.

The analysis shows that deposition and groundwater concentrations are reduced with each emissions control stage. Based on the screening groundwater estimates, the May 2018 emissions controls will result in less than 10 parts per trillion (ppt) of HFPO-DA in 87% of 781 wells, the October 2018 emissions controls will result in less than 10 parts per trillion (ppt) of HFPO-DA in 97% of 781 wells, and the 2019/2020 emissions controls (i.e. installation of a thermal oxidizer) will result in less than 10 parts per trillion (ppt) of HFPO-DA in 100% of 781 wells.

1.0 PROJECT TEAM/EXPERIENCE

Tom Wickstrom, Daniel Gomes, and Mark Garrison conducted the modeling and analyses presented here, and prepared this report. Profiles for Tom, Daniel, and Mark are included in Appendix A.

Tom Wickstrom is a Principal Consultant with eighteen years of air quality consulting experience, with a focus on regulatory air quality modeling analyses for near-field and long range transport applications. He has used his air quality dispersion modeling expertise to support Prevention of Significant Deterioration (PSD) applications in Class I and Class II areas, air toxic risk assessments, Environmental Impact Assessments (EIAs), and regional haze analyses. He has supported air quality modeling analyses for a wide variety of industrial sources and power generating facilities. He also has extensive experience in meteorological data processing and development using a wide variety of meteorological data sources and formats.

Daniel Gomes is a Technical Director at ERM's CSM practice, and a lead expert in groundwater hydrology and numerical modeling. He holds a Bachelor of Sciences in Geology and a Master of Science in Hydrogeology from the University of Sao Paulo, where he studied with Dr. Bob Cleary (Princeton Groundwater) and has 30 years of experience in a wide range of projects including groundwater contamination, water resources sustainable development, managed aquifer recharge, saltwater intrusion prevention and mitigation. Prior to his current position, Mr. Gomes was a Principal

Hydrogeologist and Modeler at Schlumberger Water Services; and General Manager of Waterloo Hydrogeologic in Canada, the makers of Visual Modflow a leading Modflow GUI.

He was also the Executive Director of a world class Groundwater Research Centre in Guelph, Canada, led by Dr. John Cherry in 2009. Mr. Gomes has successfully built over 100 groundwater models and led several groundwater contaminant fate and transport projects in many countries. A recognized groundwater expert, Mr. Gomes was the lead instructor of the National Groundwater Association' annual Modflow short training course for close to 10 years, and has been a frequent short-term Technical Expert and Capacity building instructor for United Nations Agencies such as the International Atomic Energy Agency, World Health Organization, and the World Bank.

Mark Garrison is a Partner and Technical Fellow with over forty years of experience as a meteorologist and air quality dispersion modeler in the environmental consulting field, for the electric utility industry, and for the U.S. EPA Region III. Mr. Garrison has extensive experience with permitting and air quality issues for air emissions sources for a wide variety of industries both domestically and internationally, and extensive experience in the application of air quality models and finding solutions to complex problems. His work for the Power Plant Research Program (PPRP) in Maryland includes extensive modeling of nitrogen deposition in the Chesapeake Bay Watershed and ultimately, nitrogen loading to the Bay. The work for PPRP also included development of a model to estimate the deposition of mercury in water bodies and watersheds across Maryland and throughout the Bay Watershed. Mark has extensive experience in modeling concentration and deposition impacts for input to EIA reports and risk assessment studies, and is the lead air quality modeling expert for ERM in North America.

Mr. Wickstrom and Mr. Garrison are located in ERM's Malvern, PA office. Mr. Gomes is located in ERM's Denver, CO office.

2.0 OVERVIEW OF METHODOLOGY

The key elements of this analysis include:

- Use of the latest version of the regulatory dispersion model and supporting programs: AERMOD (version 16216r), AERMAP (version 11103), and BPIP (version 04274);
- Use of the AERMOD-ready meteorological data set pre-processed by the North Carolina Department of Environmental Quality (NCDEQ) with surface meteorological data from the Fayetteville regional Airport (ICAO: KFAY, WBAN: 93740), located approximately 17 km to the north of the facility, and upper air data from Greensboro, North Carolina (ICAO: KGSO, WBAN: 13723);
- Use of a comprehensive receptor grid designed to identify modeled deposition rates within 20 - kilometers (km) of the facility;

- Modeling of annual emissions of HFPO-DA to determine the average annual total deposition (wet and dry) onto the surface, for a base case (estimated 2017 emissions) and three future cases. The average annual total deposition was determined based on five years of meteorological data.
- Deposition was determined based on AERMOD particle deposition Method 2.
- Emissions from point sources as well as fugitive sources was included. Appendix B presents the general locations of the different air emissions sources of HFPO-DA at the Fayetteville Works.
- The effect of deposition on concentrations of HFPO-DA in groundwater were estimated by applying a recharge rate (amount of rainfall entering groundwater on an annual basis) and a simplified dilution factor representing an average aquifer dilution rate for a period of one year.

3.0 METHODOLOGY: DEPOSITION MODELING

Total deposition (i.e., deposition from dry and wet removal processes) was modeled assuming particle deposition and the AERMOD Method 2 deposition option. A mean particle diameter of 1.25 microns was assumed, along with a total fine mass fraction of 94.4% (i.e., total amount of particulates assumed to be 2.5 microns in diameter or less). These particle size assumptions are supported by Barton, et al., 2012[1]. This study presented particle sizes from an ambient monitoring study of Perfluorooctanoate[2] conducted near a Chemours facility in West Virginia.

3.1 EMISSIONS AND STACK CHARACTERISTICS

Four scenarios of HFPO-DA emissions were modeled:

- Current Case - 2017 actual emissions;
- Control Case 1 – Emissions reflecting reduction due to additional air pollution controls expected by May 31, 2018;
- Control Case 2 – Emissions reflecting reductions due to additional air pollution controls expected by October 2018.
- Control Case 3 – Emissions reflecting reductions due to additional air pollution controls expected by 2019/2020.

Appendix C presents the emissions of HFPO-DA that were modeled. All emissions represent annual totals. Stack and volume source characteristics for each of the modeled sources are also included in Appendix C.

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[1] Catherine A. Barton , Larry E. Butler , Charles J. Zarzecki , John Flaherty & Mary Kaiser (2006) Characterizing Perfluorooctanoate in Ambient Air near the Fence Line of a Manufacturing Facility: Comparing Modeled and Monitored Values, Journal of the Air & Waste Management Association, 56:1, 48-55, DOI: 10.1080/10473289.2006.10464429

[2] Class of compound similar to HFPO-DA

3.2 *BUILDING DOWNWASH*

The USEPA's Building Profile Input Program (BPIP), Version 04274, was used to calculate downwash effects for the modeled point sources. BPIP version 04274 is EPA's latest version of this program, and provides the necessary building dimension information necessary for AERMOD to utilize the Plume Rise Model Enhancements (PRIME) downwash algorithm. Building configurations and locations relative to the modeled sources were obtained from specifications from the facility and input into BPIP. Appendix D presents graphical representations of the buildings and stacks that were characterized in BPIP.

3.3 *TERRAIN*

The Fayetteville Works is located in an area of relatively flat terrain. The approximate elevation above sea level of the facility is 148 feet (ft). To account for terrain elevations, the latest version of USEPA's AERMAP program (version 11103) was used to determine the ground elevation and hill scale for each modeled receptor, based on data obtained from the United States Geological Survey (USGS) National Elevation Database (NED). NED data at a 1 arc-second horizontal resolution, or 30 meters, were used in AERMAP.

3.4 *RECEPTOR GRID*

For this modeling analysis, discrete receptors were used at a resolution of 200-m, extending out to 5-km from the approximate center of the Fayetteville Works. Receptors spaced at 400-m resolution were then used from 5-km to 10-km, and finally 800-m resolution receptors were used from 10-km to 20-km. Terrain elevations and hill scale heights were determined for each receptor, as described above. A separate model run was conducted with receptors located at each of 781 sampled wells as provided by Chemours.

3.5 *METEOROLOGICAL DATA FOR AIR QUALITY MODELING*

ERM has utilized the five year (2012-2016) AERMOD-ready meteorological data pre-processed by NCDEQ collected at Fayetteville Regional Airport (ICAO: KFAY, WBAN: 93740) in this analysis. NCDEQ processed the meteorological data using AERMET (version 16216) with surface meteorological data from KFAY, located approximately 17 km to the north of the facility, and upper air data from Greensboro, NC (ICAO: KGSO, WBAN: 13723).

Although NCDEQ recommends the use of Lumberton, NC (KLBT, WBAN: 13776) meteorological data for model application sites in Bladen County , the Fayetteville Works is on the border between Bladen and Cumberland Counties. NCDEQ recommends the use of KFAY for model application sites in Cumberland County. KFAY is located approximately 16.75 km to the north of the Fayetteville Works, while KLBT is located 33.39 km to the southwest of the Fayetteville Works. Due to the significantly closer proximity of KFAY, this

station is more representative of the meteorological conditions at the Fayetteville Works than KLBT.

3.6 *METHODOLOGY: SCREENING ASSESSMENT OF EFFECTS ON GROUNDWATER CONCENTRATIONS*

ERM has estimated approximate Dilution Factors that would apply to contaminated rainfall, after it infiltrates into the ground and mixes with groundwater, for a period of one year. This section presents the methodology and results of a mixing calculation, as well as assumptions and simplifications used in the estimates.

3.6.1 *Methodology and Simplifications*

The estimated dilution factors are based on the amount of water from rainfall that infiltrates into the aquifer, in a unit area (1 m^2), divided by the total volume of groundwater stored within the same 1 m^2 of aquifer. The volume of stored groundwater is estimated by multiplying the 1 m^2 area by the saturated thickness of the aquifer, and multiplying the result by a factor representing the percentage of the saturated thickness that would mix with the infiltrating waters. The methodology attempted to use conservative values, and did not include vadose zone water content and minimal soil moisture retention.

This methodology assumes there is complete mixing of infiltrated water with the mixing zones of the aquifers within 1 year, which is a reasonable assumption considering the mixing effects of existing wells, high hydraulic conductivities and relatively high hydraulic gradients approaching the Cape Fear River. The effects of mass discharge to the river are also not included. Dilution in the perched groundwater zone was not included in the calculations.

The mixing factor is assumed to be 100% for the unconfined local aquifers, due to high permeability of approximately 70ft/day, considerable gradients at the site (0.003 ft/ft), and due to the presence of pumping wells. For the Black Creek Aquifer, considerable uncertainty exists in terms of total thickness - mixing zone factors were determined considering typical depths of deep wells in the region.

3.6.2 *Results and Limitations*

Appendix E presents the various calculations, parameters, sources of data, and resulting dilution factors. For the local unconfined aquifer the calculated dilution factors varies between 19 and 26. For the Black Creek aquifer, the values are between 17 and 37. For the purpose of this analysis, the effects on groundwater are calculated based on the dilution factor range for the local unconfined aquifer, namely 19 and 26. Appendix E also documents calculation of a recharge rate of 10.0 inches of water (compared to annual rainfall of 47.5 inches, based on the values recorded in the surface files used as input to AERMOD, averaged over five years). The recharge rate is an estimate of the amount of rainfall entering groundwater on an annual basis.

These values should be taken as a preliminary estimate that would apply to obtain the average effects on average concentrations across the aquifers considered. For more detailed point concentrations, a numerical fate and transport model is recommended, which can include local effects such as soil heterogeneities and recharge variability, as well as effects of domestic water wells and boundary conditions such as the Cape Fear River.

4.0 ANALYSIS RESULTS

To relate the modeled deposition rates (g/m^2/year, averaged over five years) to groundwater concentrations, the recharge rate of 10.0 inches of water was used to calculate the concentration of HFPO-DA entering the groundwater. This concentration was converted to parts per trillion (ppt) and then divided by the dilution factor to estimate a resulting groundwater concentration.

The analysis results are presented in two parts. The first part consists of contour plots of the total deposition rate (wet and dry) over the part of the modeling domain where groundwater samples have been collected, for the base case and for each of the three emissions control cases. These plots are presented in Appendix F. The second part consists of contour plots of the estimated groundwater concentrations due to one year of operation at the emissions levels for the three control cases, utilizing the calculation methodology explained here, for two dilution factors (19 and 26). These plots are presented in Appendix G. In addition to these plots, the modeling that was conducted at individual well locations was used to prepare Table 1. This table presents the number of wells that are predicted to fall within the ranges shown, and also presents the average predicted concentration of HFPO-DA across all wells, for each of the control scenarios for each dilution factor.

Table 1: Resulting Well Concentrations Based on Screening Assessment

Control Scenario	May 2018	May 2018	Oct 2018	Oct 2018	2019/ 2020
Total Emissions (lbs/year)	1391.7	1391.7	638.5	638.5	26.8
Recharge Rate (inches/year)	10.00	10.00	10.00	10.00	10
Aquifer Dilution Factor (one year)	19.00	26.00	19.00	26.00	19
# wells in the range shown					
<=10 ppt	681	731	760	780	781
>10 ppt	100	50	21	1	0
>20 ppt	25	3	0	0	0
>40 ppt	0	0	0	0	0
>60 ppt	0	0	0	0	0
>80 ppt	0	0	0	0	0
>100 ppt	0	0	0	0	0
>120 ppt	0	0	0	0	0

>140 ppt	0	0	0	0	0
>500 ppt	0	0	0	0	0
>3000 ppt	0	0	0	0	0
Average over all wells (ppt)	7.5	5.4	3.5	2.5	0.2

The analysis, including inspection of the plots in Appendices F and G, shows that deposition and groundwater concentrations are reduced with each emissions control stage. Based on the screening groundwater estimates, the May 2018 emissions controls will result in less than 10 parts per trillion (ppt) of HFPO-DA in 87% of 781 wells, the October 2018 emissions controls will result in less than 10 parts per trillion (ppt) of HFPO-DA in 97% of 781 wells, and the 2019/2020 emissions controls (i.e. installation of a thermal oxidizer) will result in less than 10 parts per trillion (ppt) of HFPO-DA in 100% of 781 wells.

PROFESSIONAL PROFILES

Appendix A

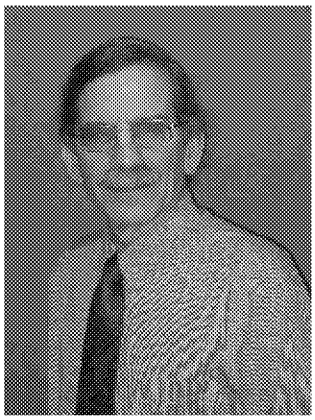
April 27, 2018
Project No. 0422611

Environmental Resources Management
75 Valley Stream Parkway, Suite 200
Malvern, Pennsylvania 19355
484-913-0300

Mark Garrison

Partner/Technical Fellow

Mark has extensive experience in the application of air quality models to assess releases of criteria and toxic air pollutants. He has detailed knowledge of the technical, regulatory, and policy issues related to dispersion modeling of new and existing sources and modeling the effects of accidental releases of toxic chemicals, and special expertise in modeling sources in complex terrain and in the application of advanced models (e.g., CALPUFF, AERMOD, CTDMPLUS). Mark has extensive experience in modeling for new and existing sources, with special emphasis on oil and gas facilities and electric utility power plants. He also has extensive experience in modeling concentration and deposition impacts for input to EIA reports and risk assessment studies. Mark served as an invited scientific peer reviewer for two EPA models: AERMOD and CALPUFF.



Experience: Over 40 years of experience as a meteorologist and air quality dispersion modeler in the environmental consulting field, for industry, and the U.S EPA.

Email: Mark.Garrison@erm.com

LinkedIn: https://www.linkedin.com/in/mark-garrison-55738578/

Education

- M.S., Environmental Science, Drexel University, 1981
- B.S., Environmental Engineering Technology, Temple University, 1977

Professional Affiliations and Registrations

- Air and Waste Management Association
- American Meteorological Society

Languages

- English, native speaker

Fields of Competence

- Air quality dispersion modeling
- Analysis of the consequences of accidental releases
- Meteorological data evaluation and processing
- Dispersion model development
- Expert testimony
- PSD and Nonattainment New Source Review (NA-NSR) modeling
- Electric utility power plant permitting
- Exposure assessment and toxic pollutant impact evaluations
- Air emissions inventory development
- Ambient impact assessments of hazardous waste sites
- Modeling in support of EIA developments
- Clean Air Act strategic planning
- Modeling in support of risk assessment
- Title V permitting

Key Industry Sectors

- Power
- Oil and Gas
- Government
- Manufacturing

Key Projects

Directed a PSD air quality modeling analysis for a new natural gas fired power generation facility in Northeast Pennsylvania. Meteorological data from a nearby tall tower were used in the analysis. An innovative technique using the Weather Research and Forecast (WRF) meteorological model was used, and approved, to demonstrate that the tall tower observations were representative of the project site in an area of complex terrain.

Conducted modeling using a Monte Carlo technique to demonstrate compliance with the 1-hour NAAQS for SO_2. This project was completed for a coal-fired power plant in Pennsylvania, and was approved by the PADEP to permit intermittent high SO_2 emissions during startup of two units using a dry scrubbing system.

Conducts modeling as the lead air quality modeling specialist for the Maryland Department of Natural Resources Power Plant Research Program (PPRP) review of several new power plant applications, including the use of AERMOD with special emphasis on addressing the 1-hour NAAQS for SO_2 and NO_2. Recent work includes use of the SCICHEM model to address secondary impacts on ozone and PM2.5 due to emissions from single sources.

Serves as an expert witness in Maryland Public Service Commission cases involving new power plant air quality impacts.

Directed and conducted modeling of SO_2 emissions from three coal-fired power plants for confidential clients to address compliance with the new 1-hour NAAQS for SO_2 (Pennsylvania and North Carolina). Modeling included exploration of numerous options for creating and using different meteorological data, the use of CEMs data to estimate the effects of actual emissions variability, and options involving the identification and processing of measured background concentrations.

Directed and conducted modeling for sulfur recovery units (SRUs) at ten facilities in Saudi Arabia. Modeling was conducted with CALPUFF and meteorological data developed using WRF and MMIF at grid resolutions down to 1.3 km. Model evaluations were performed based on measured data at 11 stations across Saudi Arabia.

Directed and conducted modeling in support of an EIA for a 2.4GW Integrated Gasification/Combined Cycle (IGCC) project north of Jazan, Saudi Arabia. Both CALPUFF and AERMOD were used to model emissions from the facility and an adjacent refinery. Meteorological data prepared by CALMET was based on WRF prognostic model wind fields.

Directed and conducted modeling in support of an expansion at a gas processing facility in Saudi Arabia. AERMOD and CALPUFF were both used in this study, and several approaches to developing meteorological inputs were tested, including: single point measurements, gridded meteorological data from MM5, single point and full profile winds extracted from MM5 output data sets. An in-depth analysis was conducted that examined the underlying scientific basis for differences in predictions between different models and different meteorological approaches.

Completed a modeling analysis of ambient impacts due to emissions from a Greenfield gas processing facility in Saudi Arabia. CALPUFF was used for this project, with meteorological data prepared by CALMET based on MM5 prognostic model wind fields. Numerous scenarios were modeled to determine the optimum plant configuration; modeling of releases from high pressure and acid gas flares was conducted to determine impacts.

Directed and conducted modeling using CALPUFF with WRF meteorological inputs for two mining projects in Canada. Analyses included modeling of hundreds of individual sources at up to 40,000 receptors, to assess compliance with ambient air

quality standards, deposition impacts to local vegetation and wildlife, and acid deposition impacts.

Directed and conducted modeling using CALPUFF with WRF meteorological inputs for an oil exploration and production project in the Atlantic Ocean off the coast of Georgetown, Guyana in South America. Modeling included consideration of offshore sources and emissions from delivery ships from shore to the project area.

Directed a study that focused on the use of developing meteorological inputs to AERMOD based on WRF model outputs processed with MMIF and AERMET, evaluating the performance of WRF compared to measured wind profiles, and evaluating the performance of AERMOD compared to measured concentrations. The study was based on the Martins Creek data set in Pennsylvania, consisting of a full year of wind profile measurements and hourly SO_2 concentrations at eight monitors in complex terrain. Results of the study were presented at an AWMA Specialty Conference (April 2016).

Directed and conducted modeling of SO_2 emissions from four coal-fired power plants for confidential clients in Texas to address compliance with the new 1-hour NAAQS for SO_2. Modeling included exploration of numerous options for creating and using different meteorological data, the use of CEMs data to estimate the effects of actual emissions variability, and options involving the identification and processing of measured background concentrations.

Directing an on-going project for a confidential client, in support of PSD permitting of a new generating station in complex terrain. The project is focused on developing meteorological inputs to AERMOD based on WRF model outputs processed with MMIF and AERMET. The modeling with WRF includes innovative approaches to developing refined land use and terrain grids which are key to simulating winds in complex terrain. A protocol was developed for review by EPA OAQPS, intended to gain approval of this approach consistent with EPA's proposed revisions to the Guideline on Air Quality Models.

Directing an on-going project for the Maryland Department of Natural Resources Power Plant Research Program (PPRP) that involves development and evaluation of WRF data sets across the State, for possible use in local scale modeling using the WRF data processed by MMIF and AERMET.

Conducted modeling and prepared a justification document for the use of the ARM2 NOx to NO_2 conversion technique, for a glass manufacturing facility in New York State. The U.S. EPA Office of Air Quality Planning and Standards (OAQPS) issued a clearinghouse memorandum approving the justification; this was the first ARM2 approval in the U.S.

Conducted modeling with the Offshore Coastal Dispersion (OCD) model to evaluate the effects of drilling operations in Block 15 off of the coast of Angola. Project included processing and evaluation of both land and overwater meteorological data.

Directed and conducted modeling in support of a proposed new refinery for a confidential client. CALPUFF was used for this analysis for estimating near-field impacts, with meteorological inputs developed from WRF prognostic model output data files. Since complex terrain was involved, the advanced terrain treatment within CALPUFF was employed and direct comparisons were made between the CALPUFF predictions and predictions from the CTDMPLUS model.

Conducted modeling in support of an aluminum smelter modernization project in New York State. The BLP, AERMOD, and CALPUFF models were evaluated as part of this project. Pollutants modeled include SO_2, NOx, and HF from stack and fugitive sources.

Conducted modeling using CALPUFF of a proposed aluminum smelter expansion project in Brazil.

Analyzed impacts of hydrogen fluoride, SO_2, NOx, and PM10 emissions to compare modeled concentrations to ambient measurements as well as for comparison to relevant ambient standards.

Conducted extensive modeling with AERMOD to evaluate the ambient impacts of potential repowering projects at two sites on Long Island, as part of a larger repowering feasibility study. Numerous optional scenarios were modeled and recommendations provided to address air quality requirements of PSD, NNSR, and the State and City Environmental Quality Review (SEQR and CEQR) processes

Utilized AERMOD to evaluate the impacts of a proposed expansion project at an aluminum refinery in Suriname. The pollutants which were evaluated included nitrogen oxides (NOx), sulfur dioxide (SO_2), carbon monoxide (CO), and particulate matter (PM). The results of the modeling analysis were compared to United States Environmental Protection Agency's (USEPA) ambient air quality standards. In addition, the impacts of emissions of hazardous air pollutants (HAPs) from the project on health risks were evaluated.

Conducted modeling of the atmospheric transport, transformation and fate of mercury emitted by coal-fired power plants and other source types for the Maryland Department of Natural Resources Power Plant Research Program (PPRP). Developed a speciated mercury emissions inventories for the Eastern U.S., and developed a simplified mercury transformation scheme that has been incorporated into CALPUFF. Model evaluations were performed comparing model predictions to, and analysis of data collected at Mercury Deposition Network (MDN) sites.

Performed a cumulative impact analysis for several new electric generation facilities in Maryland utilizing CALMET and CALPUFF, including the effect of multiple plants on visibility resources in the Shenandoah National Park and an assessment of ambient standards in Maryland.

Participated in scientific peer review panels for the new AERMOD and CALPUFF models at the invitation of the U.S. EPA. Developed comments on the scientific and performance aspects of AERMOD and CALPUFF.

Performed a full-scale analysis using the CALMET/CALPUFF modeling system to assess Nitrogen deposition to the Chesapeake Bay resulting from NOx emissions from sources located up to 1000 kilometers from the Bay. Conducted evaluations of the performance of CALPUFF and developed proposed improvements.

Performed dispersion modeling in support of accidental release assessments for Clean Air Act 112(r) Risk Management Plan for chemical, paper and other industries at over a dozen facilities using the ALOHA, SLAB, and DEGADIS models.

Conducted modeling for input to a risk assessment for a manufacturing facility in Albuquerque, New Mexico using CALPUFF for a local, complex wind application.

Prepared an expert report in support of defendant involving the effects of airborne fluoride on the environment in the vicinity of an industrial facility in Pennsylvania; was deposed by plaintiffs attorney in this case which was settled before going to trial.

Directed and conducted modeling of criteria and toxic emissions, including mercury, from a proposed waste-to-energy facility in Baltimore, MD. Modeling was conducted on behalf of PPRP as part of the environmental review of the facility, and includes modeling of NOx and SO_2 emissions to address the new 1-hour NAAQS for NO_2 and SO_2.

Daniel Gomes

Technical Director

Daniel has extensive experience in groundwater hydrology, contaminant fate and transport, and numerical modeling of complex groundwater systems such as large mine dewatering projects, saltwater intrusion, heat transfer, etc. This experience encompasses operations management, business development, projects management across various industries. An expert in groundwater modeling and quantitative hydrogeology, he has continuously advised multinationals and international agencies and has been the main instructor of several groundwater fate and transport modeling courses including NGWA's annual Modflow Course. He has extensive international experience having worked in countries in almost every continent, and has served as technical expert for International Agencies of the United Nations system.

Experience: 30 years' experience in manufacturing, mining, oil and gas, food and beverage, and government

Email: daniel.gomes@erm.com

LinkedIn: http://linkedin.com/in/daniel-gomes-9a006616

Education

- M.Sc. Hydrology
  University of São Paulo, Brazil, 2004
- B.Sc. Geology
  University of São Paulo, Brazil, 1985

Professional Affiliations and Registrations

- IAH-International Association of Hydrogeologists; NGWA (National Groundwater Association)
- Former Executive Director of GRIP – Groundwater Research and Innovation Partnerships, (currently G-360) at the University of Guelph, ON
- Technical Expert for UN organizations (IAEA, World Bank, PAHO)

Languages

- Portuguese, native speaker
- English, fluent
- Spanish, fluent

Fields of Competence

- Quantitative groundwater and hydrogoelogy
- Groundwater flow and transport modeling
- Contaminant hydrogeology, MNA, variety of contaminants
- Data management and Visualization
- Advanced geophysical logging (NMR, ECS, …)
- Fractured media characterization
- Mine Dewatering and closure (open pit; underground)
- Water supply, sustainable yield, hydrologic impacts of pumping
- Artificial recharge and ASR modeling
- Groundwater - related training services

Key Industry Sectors

- Manufacturing
- Mining
- Oil and Gas
- Food and Beverage
- Government/Water Utilities

Key Projects

Groundwater Fate and Transport Modeling of a Regional 1,4 dioxane Plume
Successfully led a team of hydrogeologists and modelers calibrate a groundwater fate and transport model in a complex fluvio-glacial system. The model was used as to optimize an existing hydraulic capture system, providing optimal locations of wells and determining most appropriate extraction rates for plume control. Work included a high resolution site characterization, definition of high permeability gravel channels and improved conceptual site model. Project was located in Northern USA; confidential client.

Source Zone Modeling for the AEROJET Superfund Site
Estimated several source zone simulations to estimate mass fluxes and determine sources depletion rates over time and overall longevity. Used the stochastic model PREMChlor to estimate TCE source initial spilled mass, mass fluxes and mass remaining in 30 source areas. Results showed that only 6% of known or suspected source areas remained active and in need of further work, with significant cost savings. Work was supervised and approved by EPA-Region 9.Rancho Cordova, client: AEROJET Rocketdyne.

Gold and Silver Mine Hydrogeology and Hydrologic Impacts Modeling in Support of EISA
Provided senior support and peer review services, as well as participated in public hearings and stakeholder Q&A sessions, including technical responses to Agency comments. The project is located relatively close to a sensitive high altitude ecosystem (paramo soils), which required a very sophisticated coupled surface water-groundwater modeling effort (Modflow USG coupled with SWACMod). Successfully help client achieve positive results with the Agencies involved as well as with local stakeholders, within an aggressive time schedule. Project is located in California, Santander Province in Colombia. Client: MINESA (Mubadala Group).

Permeable Reactive Barrier Wall modeling and optimization
Developed a site-scale fate and transport model using MODFLOW- MT3D to optimize and select the most cost effective remedial system to prevent a chlorinated hydrocarbon plume from migrating into a nearby neighborhood. Tested several designs including funnel and gate, permeable bio-walls, and in situ injection of emulsified oils (EVO system). Results allowed the client to reject the most costly solution initially imposed by local regulators (funnel and gate system). With agreement form local Agencies, an optimized EVO system was selected. Project is located in Spain, near Barcelona.

Hydraulic Barrier Capture Design and Optimization Modeling at a Factory in Japan
Provided project management and senior review of remedial design/optimization project. Used a 3-D groundwater flow and reactive transport model to design a well capture and mass removal system for a site containing chlorinated hydrocarbons. The optimized final remedy, in addition to capturing the plumes, also eliminated most of the daughter compounds formation, at an overall reduced extraction rate compared to the initial design. This led to significant long-time savings for the client. Client: confidential Multinational Corporation.

Optimization of an Air Sparging System in Brazil
Successfully optimized an air sparging barrier using a multi-phase model (MODFLOW Surfact), within a tidal-influenced river environment. Results showed that the barrier was inducing a benzene plume by-pass due to longer than required air injection cycles that pushed the plume away from the treatment barrier. Injection cycle times were reduced from 8hrs/day to 2 hours per day, which promoted more efficient stripping of the plume as well as reduced plume by-pass, resulting in reduced fuel burning needs and significant cost savings. Client:

Multinational Corporation. Project is in Cubatão, Brazil.

Peer Review of Coal Mine Closure Project in Australia.
Currently providing senior review of a coal mine open pit recovery/closure. The project is located close to an urban center and near other mines, which constitutes a very difficult environment to model. The client trusted ERM experts to help ensure the model is consistent with the highest standards, well calibrated and fully representative of the geological conditions, so that accurate pit recovery conditions are achieved.

Peer Review of a groundwater modeling litigation case involving remediation of PFAS compounds.
Currently serving as a member of an expert panel of senior reviewer including data analysis and modeling set up, calibration and predictions for a large model, including defining the location of a new water supply system for a nearby system.

Fly Ash Deposit Closure Modeling and Impact Assessment. Supervised fate and transport modeling of a fly ash deposit in the banks of the Mississippi river in Illinois. Supervised the simulation of a number of CoCs including Sulfate, Iron, Manganese and Boron for a period of 30 years following the proposed cap installation. Client: Grand Tower Energy Center LLC.

Groundwater fate and transport model of pesticies for Risk Assessment
Completed the development of a 3D groundwater flow and transport model to determine potential receptors and determine point concentrations for risk assessment/management. Pesticides included Phenoxy compounds and chlorophenols. Model indicated that decay rates would not produce external receptors. Location: New Zealand, confidential client.

Key Projects Prior to Joining ERM

Training Systems
Provided training services on data management systems and initial data migration services, consolidating several years of data into an MSSQL Server using SWS' software solution Hydro GeoAnalyst. Project was located in Northwestern Territories, Canada.

Saltwater Intrusion Risk Assessment In Panama
Provided technical guidance for a saltwater risk assessment project in Panama. Project involved TDEM survey at a coastal area and preliminary SEAWAT modeling of saltwater migration (density-dependent model) to establish safe pumping yield. Client: Coca Cola FEMSA, Panama City.

Resolution Cooper Underground Mine Historic Dewatering/Recovery Flow Model
Provided senior level management for a Modflow Surfact for a total of over 80 years of flow and head calibration targets for a project in Arizona. Completed 3-D visualization and animation of pit recovery and dewatering over the years. Calibrated the model.

Pierina Pit Closure and Post Closure Water Quality Modeling
Developed a MODFLOW Surfact model for a project in Peru to estimate pit inflows and post closure pit lake formation/ development of mitigation measures.

Mine Tailings
Modeled the mine tailings regional 3-D flow and particle tracking models for seepage control and environmental impact assessment for a project in Chile.

Mine Dewatering Models
Provided senior level reviewing for models in Chile (MODFLOW/FEFLOW), including the largest underground copper mine in the world.

Bauxite Mining Site Risk Assessment/Mitigation
Provided model review and supervision of a finate elements red mud model at a bauxite mining site in Jamaica. Used a FEFLOW Finite Element model to simulate density-dependent sodium contamination fate and transport in a fractured-faulted carbonate media.

Groundwater Supply Sustainability Modeling for Mine Process Water
Supervised the development of several three-dimensional groundwater flow models, linked to GIS databases in northern Chile, to determine sustainable yields, assess hydrological risks to wetlands, and determine optimal pumping wells locations/depths. Client: multinational mining companies from US and Canada operating in Chile.

Santa Susana Field Laboratory Discrete Fracture Network conceptual modeling
Managed and reviewed a discrete fracture network modeling effort at a superfund site in California. Applied advanced Schlumberger fracture detection and parameter estimate logging tools, and a sophisticated data analysis software to identify fracture networks at the site.

Jet Fuel Plume Soil Vapor Extraction Modeling
Developed a 3-D flow model to simulate the capture efficiency of soil vapor extraction/injection systems in Alaska to remediate a jet fuel plume. Based on model results, regulators approved the deactivation of the existing SVE system and monitored natural attenuation as the main remedy for the site.

Mine Dewatering System Desing And Long Term Projections
Developed and calibrated the model to estimate long-term dewatering requirements and simulate dewatering works for a project in Chile. Trained local staff to use the model for future simulations.

3D Mine Dewatering Model (MODFLOW)
Performed long-term predictions of dewatering requirements and optimized system design for a project in Chile.

Saltwater Brine
For a Canadian mining company in Chile, evaluated the risk of saltwater brine uplifting due to pumping with a density-dependent Finite Element model (FEFLOW).

3D Groundwater Flow Model
Developed a model of the Northern Sector of the Salar de Atacama aquifer, for a Canadian mining company in Chile.

3D Mine Dewatering Model Audits
Audited MODFLOW for two clients in Sao Paulo, Brazil. Assessed model adequacy and limitations, and provided advice for improvement to support long-term predictions of dewatering requirements and regional hydrologic impact evaluation.

Coal Mine Acid Drainage
Managed a large-scale site assessment, modeling, and remedial design of a Brazilian coalmine for closure and reclamation purposes.

Island Operable Unit RI/FS Project
Peer reviewed a large transient groundwater flow and particle-tracking model developed by a local consultant in California to evaluate pump and treat capture. Built a geological-geophysical database system.

Site-wide Feasibility Study Fate and Transport and Optimization Models
Reviewed a flow and particle tracking groundwater MODFLOW model prepared by a local consultant in California for capture zone analysis. Improved the existing model by adding a system of paleo-channels and aquitard windows, not previously identified, to be used for dual-domain fate and transport simulation of Natural Attenuation and other remedies.

RT3D Parent-Daughter Degradation Chain Model
Developed a TCE–DCE–VC plume in Toronto, Ontario. Developed remedial alternatives using cut-off walls and pump and treat alternatives.

3-D Modflow-Modpath Modeling Project
Reviewed with the purpose of evaluating funnel-and-gate systems design (TCE plume) for a project in Canada.

Senior Fate and Transport Modeler
Modeled a high-level case of naphthalene containment simulation near Vancouver, Canada. Successfully defended a partial cut-off, natural attenuation approach using a deep cut-off wall to increase time of travel and allow for natural decay of naphthalene.

Benzene and Naphthalene RI/FS Projects
Served as Senior F&T Modeler for several projects for a large iron and steel multinational company in Rio de Janeiro, Brazil.

Human Health Risk Assessment
Participated as senior F&T modeler as part of a large RI/FS of a multi-PRP site in Sao Paulo, Brazil, involving over 10 multinational companies. Supervised and audited a 3-D Modflow – MT3D model used to evaluate receptor point concentrations over time, as well as for remedial design simulations.

Environmental Audit
Audited the third largest gold mine and smelter in the Amazon Rain Forest region.

Groundwater Contamination Arbitration
Served as a Senior Modeling Auditor for an arbitration case in Florida. On behalf of the City of Gainesville, reviewed an existing MODFLOW/MT3D model prepared by the PRP consultant in order to verify its ability to predict Naphthalene plume migration rates to the city's well field. Detected and corrected errors in the input files and conducted a predictive uncertainty analysis. Results showed that the plume could reach the well field within 1/10 of the time originally predicted. Later confirmed this with additional monitoring.

Deep Plume Impact Mitigation to City Wellfield
Evaluated groundwater pumping requirements to capture deep plumes from the Koppers Superfund Site to the City of Gainesville, Florida Muphree well field.

Senior Review of Integrated Surface Water/Groundwater Replenishment Project
Supervised the development of the Mojave R-cubed (http://r3project.com/) integrated modeling project (ECLIPSE coupled surface water – variable saturation groundwater model). The model helped the client design a river infiltration system that was later implemented and helped the region endure the recent severe droughts that affected most of the State.

Sao Sebastiao Aquifer Zoning Project
Consulted for the project in Bahia, Brazil, which included elaboration of a GIS-Data base, hydrogeological quality mapping, and elaboration of a three-dimensional MODFLOW groundwater flow and particle tracking model. Assessed the wellhead capture zone and quantified groundwater reserves and sustainable yield. Created a Groundwater Management Plan.

Groundwater Flow Model
Reviewed the groundwater flow model of the city of Bogotá, Colombia (5 million people).

Wellhead Protection Project
Managed the project for the Municipality of Caçapava, Brazil, based on a unique Modeling - GIS - Risk Assessment Methodology.

Technical Expertise
Provided expertise in six IAEA missions to Tacna, Peru; Caracas, Venezuela; and Montevideo, Uruguay. Provided hands-on training on groundwater

modeling, and evaluated hydrogeologic data for the development of 3-D flow models.

3D Flow and Transport Models
Developed seven models to evaluate remedial alternatives for groundwater clean-up in Brazil.

Phase 1 and 2 Site Assessments
Managed assessments and clean-up projects of 11 high profile sites contaminated with chlorinated solvents (PCE, TCE) and pesticides (PCP, Hexachlorobenzene) in São Vicente, Brazil. Developed groundwater flow and transport models where clean-up alternatives were evaluated. Successfully helped clean-up level negotiations with Environmental Agencies and the Public Ministry.

Clean-Up Feasibility and Pilot Pumping Test
Managed the project for a chemical company with an acid wastes site in Bahia, Brazil. Developed a two-dimensional, finite elements flow and transport model for plume capture and clean-up time estimate.

Environmental Impact Assessment
In Triunfo, Brazil, assessed the third largest petrochemical complex in Latin America (upgrading of existing installations). Managed multi-disciplinary team.

Site Assessments
Performed assessments and designed pump-and-treat remediation systems at several gas stations and storage facilities in Brazil.

Human Health Risk Assessment
Conducted soil, groundwater, wipe, and asbestos sampling for a decommissioned multinational lighting company in Recife, Brazil.

Performance Evaluation
Developed a performance evaluation of a petrochemical landfarming unit in Bahia, Brazil.

Hazardous Wastes Landfill Environmental Impact Study
Completed project permitting and negotiated with environmental authorities and local political and community leaders in Araraquara, Brazil.

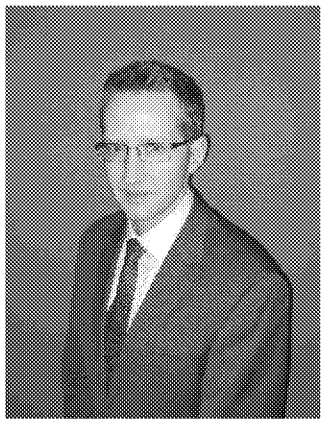
Environmental Audit
Audited the third largest gold mine and smelter in the Amazon Rain Forest region near Carajás, Brazil.

Groundwater Cleanup Project
Audited the project at a chemical complex in Maceió, Brazil. Prepared the second opinion report for the Brazilian Institute of Environment (IBAMA).

Thomas Wickstrom

Principal Consultant

Tom has extensive experience in conducting air quality modeling analyses for near-field and long range transport applications. He has used his air quality dispersion modeling expertise to support Environmental Impact Assessments (EIAs), Prevention of Significant Deterioration (PSD) applications in Class I and Class II areas, and regional haze analyses. He also has extensive experience in meteorological data processing and development using a wide variety of meteorological data sources and formats. Toms' permitting experience includes PSD/NSR applicability determinations and emissions inventory development for PSD/NSR projects, as well as minor source permit to construct application development, Title V and minor source operating permit requirements determination, and Title V permit application development.



Experience: 18 years of experience in the environmental consulting field, with a focus on air quality dispersion modeling and air quality permitting.

Email: Tom.Wickstrom@erm.com

LinkedIn: https://www.linkedin.com/in/thomas-wickstrom-07792531/

Education

- B.S., Meteorology, Pennsylvania State University, 1999

Professional Affiliations and Registrations

- Air and Waste Management Association (AWMA)

Languages

- English, native speaker

Fields of Competence

- Air quality models including CALPUFF, AERMOD, ISC-PRIME, ISCST3, and CTSCREEN
- Use of standard meteorological processors such as CALMET and AERMET
- Site-specific meteorological data processing
- Prognostic meteorological data for use in regulatory air quality modeling
- PSD and NSR permitting
- Title V permitting and related issues including annual emissions reporting and compliance certification
- Analysis of emission inventories and evaluations for modeling analyses
- GIS
- Meteorological monitoring
- FORTRAN programming

Key Industry Sectors

- Power
- Oil and Gas
- Government
- Manufacturing

Key Projects

Air Quality Modeling and Monitoring

Directed the PSD air quality modeling analyses for three separate natural gas power plant projects being developed in parallel. The projects were located in northcentral Pennsylvania, northcentral West Virginia, and in the Ohio Valley panhandle region of West Virginia. One of the projects required an extensive demonstration of meteorological data representativeness in order to use available airport meteorological data. All three projects required cumulative air quality modeling. Also supported the project post application submittal to assist with responses to public comments.

Assisted with a PSD air quality modeling analysis for a new natural gas fired power generation facility in northeast Pennsylvania. Meteorological data from a nearby tall tower were used in the analysis. An innovative technique using the Weather Research and Forecast (WRF) meteorological model was used to demonstrate that the tall tower observations were representative of the project site in an area of complex terrain.

Directed modeling analyses at multiple sites for compressor stations located along a new natural gas pipeline project. The air quality modeling analyses were performed in four states, West Virginia, Pennsylvania, Virginia, and North Carolina. The analyses addressed permitting requirements of multiple programs across the different project sites: FERC, PSD, and state-only air quality programs.

Directed a PSD air quality modeling analysis for a new wood products manufacturing facility in central North Carolina. The analysis included an extensive cumulative modeling analysis due to the project's location in a relatively heavily industrialized area. Ozone was addressed as a PSD pollutant due to large emissions of NOX from the proposed project, using new guidance from EPA on tier 1 ozone assessments. Successfully negotiated the use of tier 1 in lieu of time consuming project-specific full photochemical modeling.

Supported the review of air quality dispersion modeling analyses to for ongoing power sector permitting activity in the State of Maryland. Acted on behalf of the Maryland DNR to provide comments and critical review to Maryland Public Service Commission licensing applicants, and to support the State's testimony in each case.

Responsible for a PSD air quality modeling analysis for a new natural gas fired power generation facility along the Ohio River in Marshall County, West Virginia. Meteorological data from a nearby 100 m tower and SODAR system were used in the analysis. The analysis included cumulative assessment for the 1-hr NO2 NAAQS.

Responsible for a PSD air quality modeling analysis for new a peaking power generation facility in Grimes County, TX. The Texas Commission on Environmental Quality (TCEQ) identified ozone formation potential from the project to be a critical component of the PSD permitting process, due to location relative to ozone nonattainment areas and high ambient ozone levels. Air quality impacts for ozone were determined based on a screening modeling analysis negotiated with the Texas Commission on Environmental Quality. The air quality modeling analysis demonstrated that all project related impacts were below significance levels.

Conducted a PSD air quality modeling analysis for an industrial gas support facility in Bayport, Harris County, TX. The project involved repowering the existing facility's boiler and combustion turbines. The air quality modeling analysis demonstrated that all project related impacts were below significance levels, which avoided the need for extensive

cumulative modeling analyses in a highly industrialized area.

Completed two air quality modeling analyses for proposed offshore oil production platforms in the western Gulf of Mexico. The analyses were performed to assess compliance with Class I and Class II significant impact levels for NO2 onshore, as well as AQRVs in a nearby Class I area. CALPUFF was used for all modeling analyses, with VISTAS CALMET meteorological data as well as CALMET meteorological data derived from MM5 and observations. The project fell under the jurisdiction of the Bureau of Ocean Energy Management.

Performed an air quality modeling analysis of a proposed offshore well drilling operation in the Emirate of Abu Dhabi, United Arab Emirates (UAE). The air quality modeling analysis considered the impacts of both the construction phase and the well testing and cleaning phase of the project. The effects of these operations on air quality onshore were determined through the use of CALPUFF and were compared with UAE standards.

Assisted with air quality modeling analyses for a large Integrated Combined Cycle Gasification (IGCC) facility proposed for a new refinery project on the Red Sea coast in Saudi Arabia. The CALPUFF model was used, as it was preferred by the reviewing authorities. Assisted with the development of various post processing techniques to demonstrate project impacts relative to the specific forms of the relevant air quality standards in this region. Worked closely with the project engineering contractor to identify designs that comply with air quality standards.

Conducted a complete PSD air quality modeling analysis for an industrial facility for future planning purposes. The analyses performed were for both Class I and Class II areas, using AERMOD, CALPUFF, and VISCREEN dispersion models. The most recent version of AERMOD was used with Tier III NO2 modeling assumptions. The objective of the project was to identify any 'fatal flaws' that may exist pertaining to the newly promulgated NAAQS for SO2 and NO2, and PM2.5. This project added substantial value to the client in that in the event that a proposed modification should trip PSD permitting requirements, the outcome of any subsequent air quality modeling analysis would be already known.

Conducted refined air quality dispersion modeling analyses for a local county government in Pennsylvania to assess compliance with new NAAQS standards for Lead (Pb). The county had been identified as being partial nonattainment for the new Lead standard due to the impact from local industries. The local government was concerned about over-designating the nonattainment area. A comment document was assembled for submittal on behalf of the local government to EPA, which provided justifications for more specific non-attainment area designation.

Provided an assessment of the implications of the new NO2 standard, as it pertains to an industrial client's operations. A custom post-processor for AERMOD was developed to create model design concentrations in the statistical form of the new NAAQS.

Developed a unique approach to assembling a site specific profile of wind speed and wind direction for a remote site in the desert southwest United States. The profile was created by merging surface observations with off-site wind observations from locations situated in higher terrain. Various analytical and statistical techniques were used to demonstrate that the observations from the higher terrain locations were representative of expected high level profile winds over the surface observation site. The wind profile data were assembled for input into a dispersion modeling application. This exercise was necessary to replace a problematic remote sensing system.

Assisted with the development of multiple air quality modeling analysis using as wide assortment of dispersion models and input meteorological data for an air quality modeling evaluation in the Middle East.

The goal of the project was to use common practices to establish compliance with air quality criteria, and subsequently challenge the results with an array of alternate analyses designed to assess model performance and model applicability in this region of the world. Meteorological data based on observations as well as data derived from prognostic models were used.

Conducted a modeling analysis for air toxics for a facility identified by EPA as being a concern for toxic air pollution near schools. The analysis required multiple runs and sensitivity evaluations to assess the client's potential liability.

Developed meteorological data for use in a CALPUFF analysis to support an EIA for a large oil refinery in Saudi Arabia using MM5 prognostic data. The coastal setting of the application site was critical to the meteorological data quality analysis, and the land/sea interaction had to be accounted for in the meteorological data to be used in CALPUFF.

Conducted a refined CALPUFF analysis for a confidential client using meteorological data derived from the WRF meteorological model. The application site was situated on a Caribbean island, and the island's complex terrain played a major role in the analysis. A comparative analysis was conducted between various complex terrain treatments within CALPUFF, as well as the CTDMPlus model and CALPUFF. All meteorological data used in either CALPUFF or CTDMPlus were derived from the WRF data.

Developed site-specific micrometeorological data using custom land use to support a PSD application for a large automotive plant in the southeastern US. The analysis was necessary to demonstrate the land use characteristics associated with the future developed site are comparable to the land use characteristics of the nearby airport meteorological data used in the PSD modeling analysis.

Assisted with dispersion modeling analyses for aluminum manufacturing facilities in the US and Algeria. Comparative analyses of CALPUFF, AERMOD, and BLP were performed.

Developed AERMOD ready meteorological data to support an EIA for a cement manufacturing facility in Indonesia. The development of these data required custom processing to account for the relatively poor data completeness in the region.

Developed custom data processing routines to process raw wind speed and direction data from a Doppler SODAR system. Multiple sensitivity and performance analyses of the SODAR were performed.

Conducted regional CALPUFF modeling using fine resolution MM5 data for the LA Basin. The modeling was conducted to calculate atmospheric deposition of various pollutants for a confidential client.

Conducted modeling analyses to determine the impacts of visible water plumes from power plant scrubbers. Used original, non-regulatory techniques to verify plume impacts on sensitive areas.

Performed confidential, attorney-client privileged air quality modeling to assess a facility's compliance with ambient air quality standards. The results of the analyses were used for future planning purposes.

Conducted multiple air quality modeling analyses to support PSD permit applications for industrial facilities. These analyses included both Class I and Class II area impacts.

Completed several visibility modeling analyses for facilities in the southeast as part of compliance with the BART rule. These studies involved analyses to exempt sources from the BART rule, or to

demonstrate the effects of theoretical add-on controls on visibility in Class I areas.

Conducted several CTSCREEN modeling analyses for facilities in complex terrain, including a CTSCREEN study for a Class I area in West Virginia.

Performed air toxics and state only required modeling analyses for various industrial sources. Some air toxics modeling was conducted under attorney-client privilege for future planning purposes.

Installed a complete meteorological monitoring system to collect data for a PSD modeling analysis. The system included a multi-level meteorological tower and a Doppler SODAR.

PSD, NSR, Title V, and Emissions Inventory Projects

Assembled project emissions inventories for several industrial facilities undergoing major modifications. The emissions inventories were used for PSD/NSR applicability as well as for input into modeling analyses.

Conducted annual emissions reporting for complex industrial operations involving a large number of individual reporting emissions units. Responsible for raw data collection and QA as part of this effort.

Designed spreadsheets for industrial facilities to use to track emissions against permit limits. The spreadsheets also were used to summarize annual emissions for reporting purposes.

Conducted annual compliance certification for a small manufacturing facility with complex compliance requirements relating to chemical usage. Identified areas were company staff were not meeting the requirements of the permit.

Publications

- Wickstrom, T., M. Garrison, S. Ramaswamy "Practical Applications of Prognostic Meteorological Models to Support Air Quality Permitting", AWMA Air Quality Modeling Specialty Conference Proceedings, November 2017
- Wickstrom, T., K. Ramaswamy , M. Garrison, "Prognostic Meteorological Data: A New Approach for Representative Meteorological Data in regulatory Dispersion Modeling Applications", EM - The Magazine for Environmetal Managers, October 2016
- Wickstrom, T., M. Garrison, S. Ramaswamy, J. Sherwell "Evaluation of Proposed Appendix W Recommendations for the Use of Prognostic Meteorological Data in regulatory Air Quality Modeling with AERMOD", AWMA Air Quality Modeling Specialty Conference Proceedings, April 2016
- Barfield, E., R. Hamel, M. Garrison, T. Wickstrom "Variable Emissions in Air Quality Dispersion Modeling", Poster presentation to the AWMA MEGA Symposium, August 2014
- Wickstrom, T., M. Garrison, A. Yegnan, J. Sherwell "Evaluation of the Urban Option in AERMOD – Modeled Sensitivity for a Scrubbed Coal Fired Power Plant Stack", AWMA Air Quality Modeling Specialty Conference Proceedings, March 2013
- Wickstrom, T. "Site-Specific Meteorological Monitoring for AERMOD: Model Sensitivity to Measurements of Solar and Net Radiation", AWMA 2010 Annual Conference and Exhibition Proceedings, June 2010
- Wickstrom, T., M. Garrison, J. Sherwell. "A Look at Fogging and Icing Impacts from a Wet Flue Gas Desulphurization (FGD) System", AWMA 2008 Annual Conference and Exhibition Proceedings, June 2008
- Wickstrom, T., M. Garrison, A. Yegnan, J. Sherwell "Exploring the use of Prognostic Model Meteorological Outputs with AERMOD", AWMA 2008 Annual Conference and Exhibition Proceedings, June 2008

- Sherwell, J., M. Garrison, T. Wickstrom, A. Yegnan, M. Castro, C. Moore “Progress Towards Evaluating and Modeling Long-Term Patterns of Speciated Mercury Concentrations in Maryland Using CALPUFF”, Poster presentation to the National Atmospheric Deposition Program annual meeting, September 2007

LOCATION OF EMISSIONS SOURCES

Appendix B

April 27, 2018
Project No. 0422611

Environmental Resources Management
75 Valley Stream Parkway, Suite 200
Malvern, Pennsylvania 19355
484-913-0300

Figure B-1
Location of Emissions Sources
Chemours Fayetteville Works

N

0 m 100 m 200 m 300 m 400 m 500 m

EMISSIONS AND SOURCE CHARACTERISTICS

Appendix C

April 27, 2018
Project No. 0422611

Environmental Resources Management
75 Valley Stream Parkway, Suite 200
Malvern, Pennsylvania 19355
484-913-0300

Table C-1 – Emissions of HFPO-DA – Annual Emission Rates

2017 Base Case

Source	Process Vent (lbs)	Indoor Equipt (lbs)	Outdoor Equipt (lbs)
VE_North	1506.4	2.5	1.7
VE_South	114	1.6	0.4
PPA	638.8	31.2	1
Polymers	4.8	0	0
Semi-works	0.15	0.05	0

Assumptions (all cases):

1 - Process Vent for VE-North, VE-South, PPA are scrubber emissions
2 - Indoor Equipment is vented to the stack but post-scrubber
3 - Outdoor Equipment represents fugitve emissions, modeled as volume source in AERMOD

October 2018 Case

Source	Process Vent (lbs)	Indoor Equipt (lbs)	Outdoor Equipt (lbs)
VE_North	VE_North	1355.76	0.25
VE_South	VE_South	7.4	0.1
PPA	PPA	19.164	0.936
Polymers	Polymers	4.8	0
Semi-works	Semi-works	0.15	0.05

October 2018 Case Assumptions:

1 - Additional 60% Control Efficiency to VE-North scrubber
2 - VE-S PPVE campaign resumed
3 - VE-S Indoor Equipment controled by carbon adsorber

May 31 2018 Case

Source	Process Vent (lbs)	Indoor Equipt (lbs)	Outdoor Equipt (lbs)
VE_North	1355.76	0.25	1.7
VE_South	7.4	0.1	0.4
PPA	19.164	0.936	1
Polymers	4.8	0	0
Semi-works	0.15	0.05	0

May 31 2018 Case Assumptions:

1 - Additional 10% Control Efficiency to VE-North scrubber
2 - VE-North Indoor Equipment controled by carbon adsorber
3 - No PPVE campaign from VE-South
4 - PPA Process Vent and PPA Indoor Equipment controled by carbon adsorber

2019/2020 Case

	Process Vent (lbs)	Indoor Equipt (lbs)	Outdoor Equipt (lbs)
VE_North	1.5064	0.25	1.7
VE_South	0.114	1.6	0.4
PPA	19.164	0.936	1
Polymers	0.0048	0	0
Semi-works	0.15	0.05	0

2019/2020 Case Assumptions:

October 2018 assumptions with the addition of:
1 - 99.99% control of VE-N and VE-S via thermal oxidizer

Table C-2 Modeled Stack and Fugitive Physical Source Parameters

Stack Sources					
Point Source ID	**Description**	**Height (m)**	**Temp (K)**	**EV (m/s)**	**D (m)**
DIV	Vinyl Ethers North Division Stack	25.91	305	20.75	0.914
VE_S	Vinyl Ethers South Stack	24.69	291	35.82	0.701
PPA	PPA Process Stack	25.91	296	32.62	0.481
POLY	Polymer Process Stack	22.86	283	12.15	0.762
SEMI	Semi-Works Process Stack	8.47	292	10.59	0.686

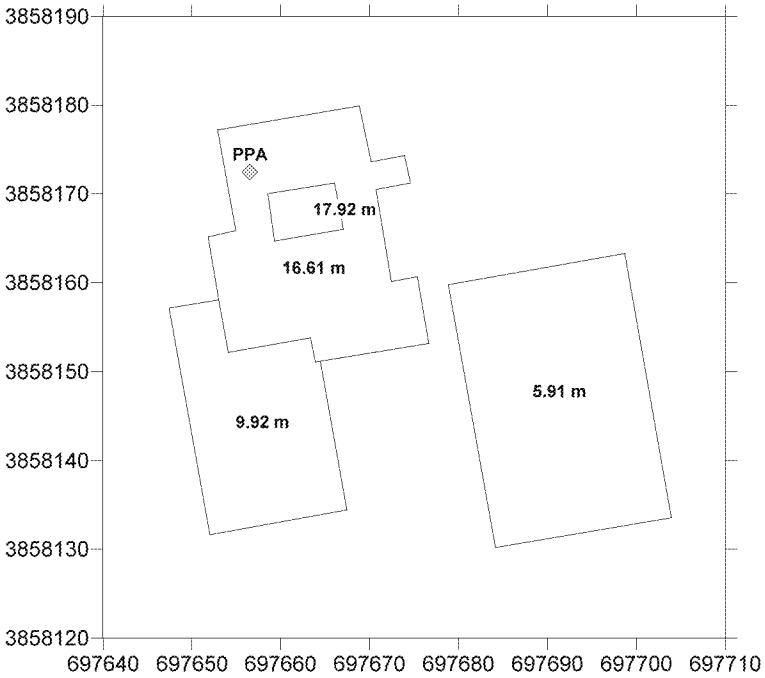
Fugitive Sources				
Volume Source ID	**Description**	**Release Height (m)**	**σY (m)**	**σZ (m)**
VE_NF	Vinyl Ethers North Fugitives	4.57	2.09	4.25
VE_SF	Vinyl Ethers South Fugitives	14.63	1.56	13.61
PPAF	PPA Fugitives	3.17	3.49	2.95

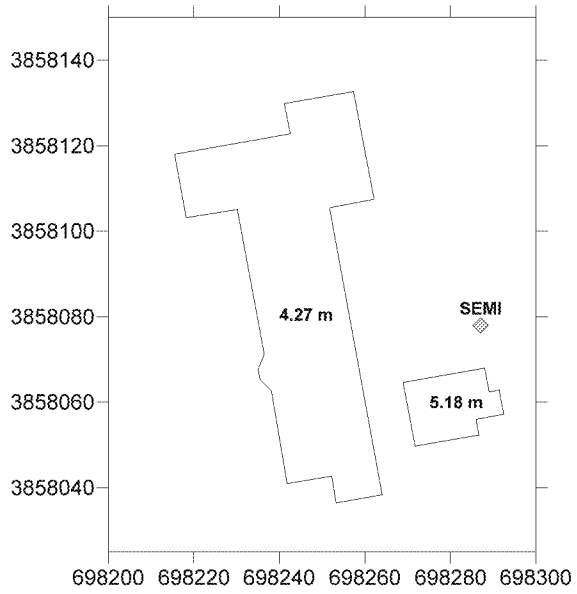
MODELED POINT SOURCES AND BUILDING DIMENSIONS

Appendix D

April 27, 2018
Project No. 0422611

Environmental Resources Management
75 Valley Stream Parkway, Suite 200
Malvern, Pennsylvania 19355
484-913-0300





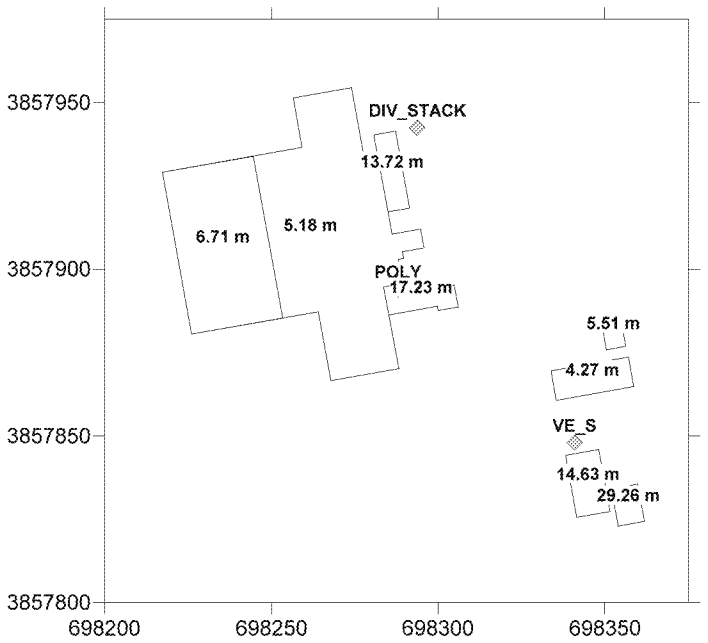


Figure D-1
Modeled Point Sources
and
Building Dimensions

Coordinates in UTM Zone 17 North American 1983 Datum (meters)

CALCULATION OF RECHARGE RATE AND DILUTION FACTORS

Appendix E

April 27, 2018
Project No. 0422611

Environmental Resources Management
75 Valley Stream Parkway, Suite 200
Malvern, Pennsylvania 19355
84-913-0300

1-year Dilution Factor Calculations

1. Calculation of Rain volume in 1m2 of aquifer: Recharge value x 1m x 1m

Parameter	Average value	units	notes	
Total Annual Rainfall	47.5	inches/year		
Evapotranspiration	32.3	inches/year	68% of rainfall(*)	
Run-off	4.7	inches/year	10% of rainfall (*)	
Soil retention	0.47	inches/year	1% of rainfall	
Recharge to groundwater	10.0	inches/year		conversion inch to ft
Final Recharge Volume in 1 year (in 1 m2)	0.253	m3		0.0254

(*) - values from North Carolina Water Budget website (https://www.ncwater.org/Education_and_Technical_Assistance/Ground_Water/What/budget.html)

2. Estimation of stored groundwater volumes : Volume = 1m x 1m x Saturated Thickness of mixing zone

Parameter	Aquifer				
	Local Unconfined system		Black Creek Aquifer		
	Min	Max	Min	Max	
Total Porosity (*)	40%	48%	40%	48%	
Saturated Thickness (**)	40	45	120	160	
% of saturated Thickness mixing with rainfall	100%	100%	30%	40%	
Total Estimated mixing groundwater volume (1 year)	4.9	6.6	4.4	9.4	0.3048

(*) - estimated typical parameters for medium to fine sands in both aquifers

(**) - estimated based on Parsons (2018)

3. Estimation of approximate one-year dilution factor ranges (volume of rainfall in 1 square meter divided by volume of groundwater in 1 square meter of aquifer

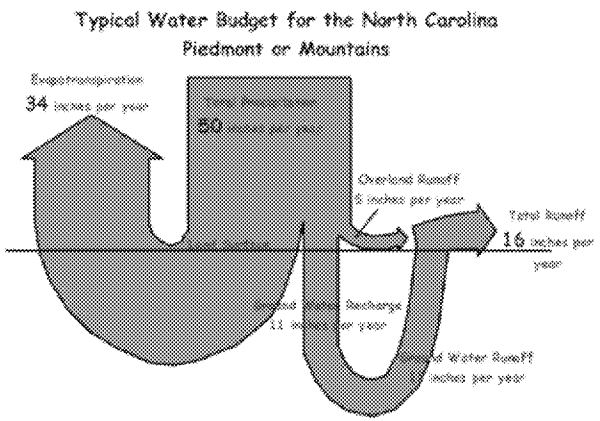
	Aquifer			
	Local Unconfined system		Black Creek Aquifer	
	Min	Max	Min	Max
Dilution Factor	19	26	17	37

Assumptions:

(*) considers full mixing of rainfall in groundwater to the estimated mixing percentage of saturated thickness in 1 year

References:

PARSONS (2018), Additional Site Investigation Report Chemours Fayetteville Works Site. Rcra Permit No. NCD047368642-R1, March 30, 2018



ratio ET/PPT	0.68
ration runoff/I	0.1

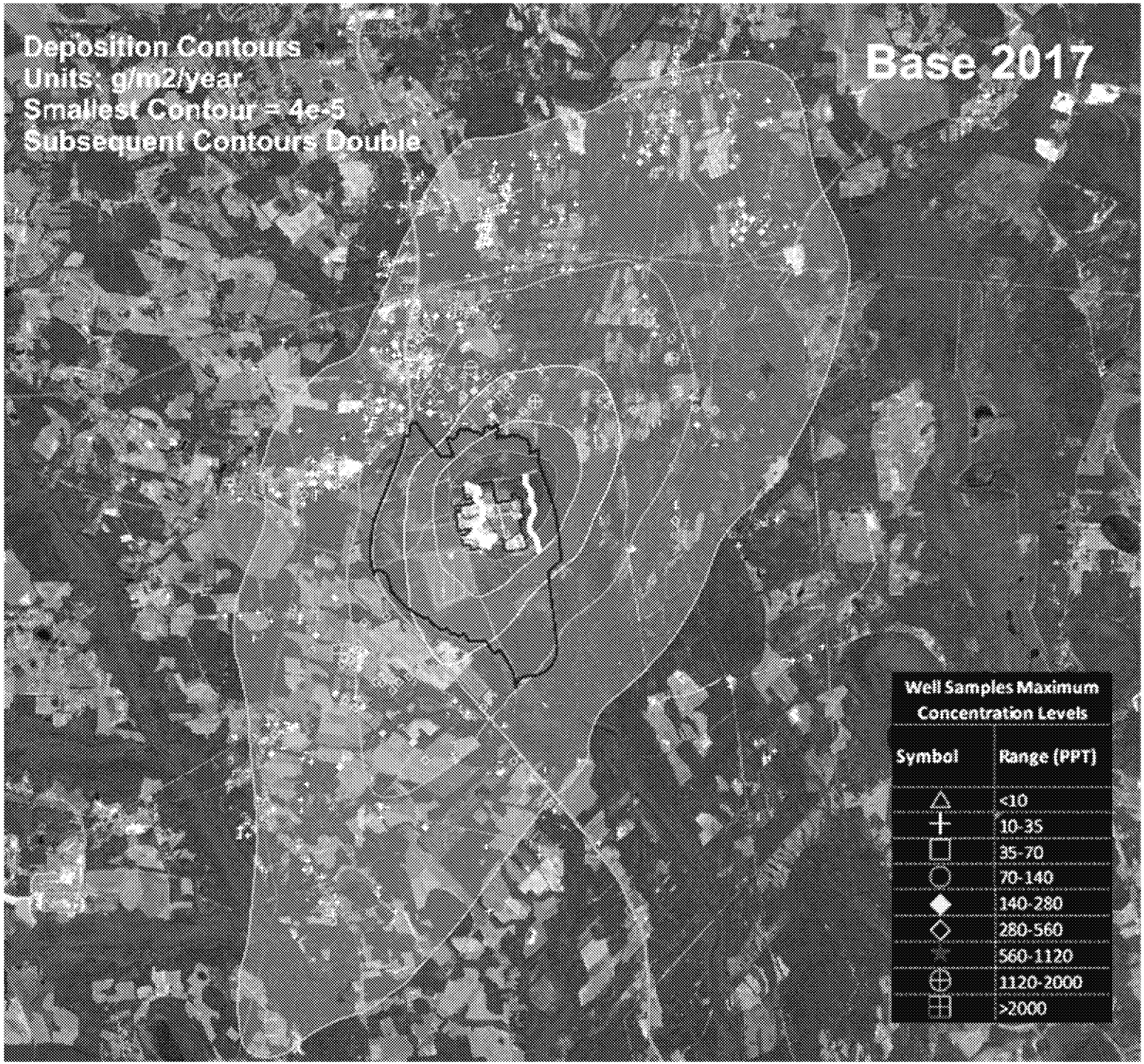
source: https://www.ncwater.org/Education_and_Technical_Assistance/Ground_Water/What/budget.html

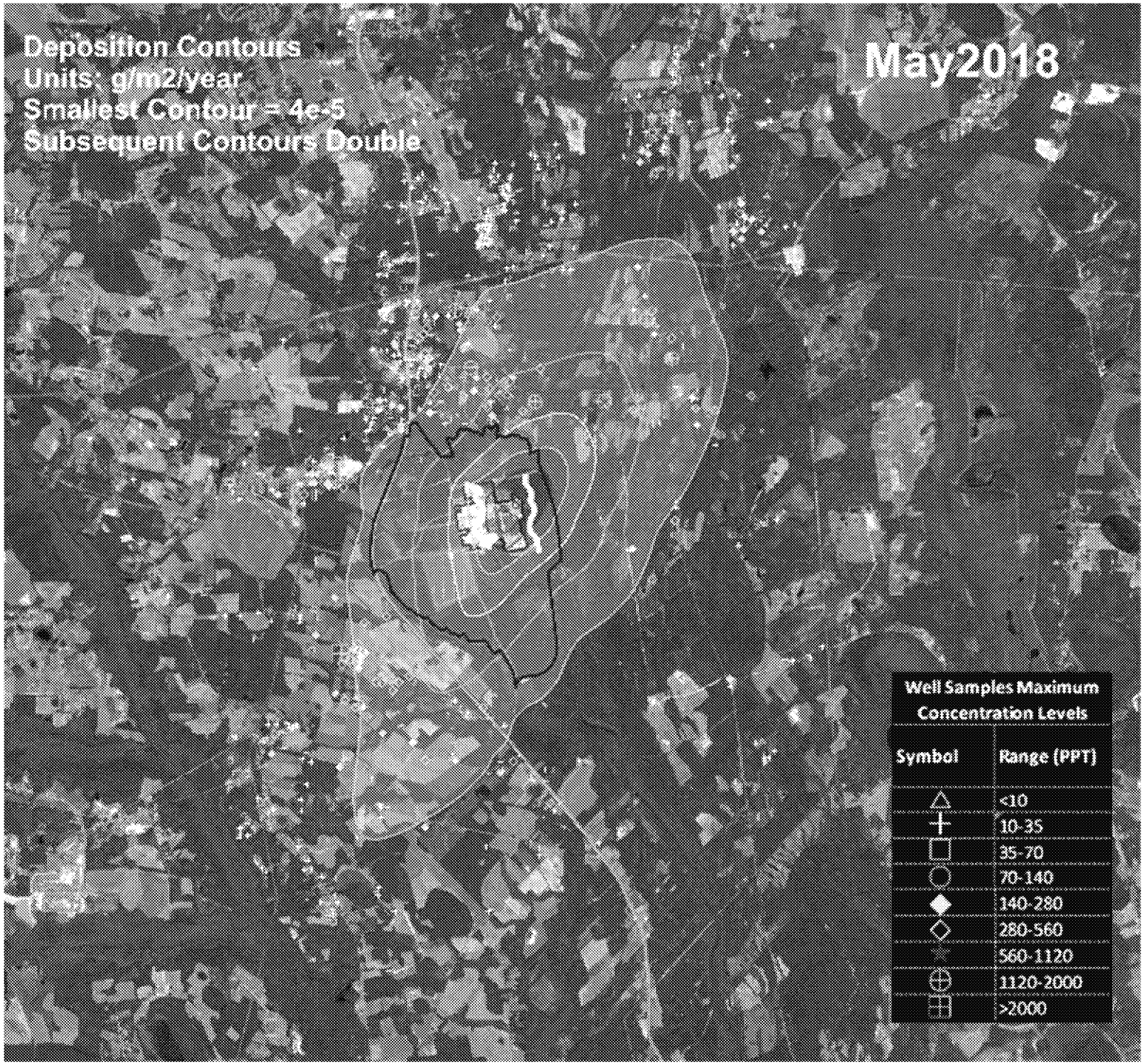
DEPOSITION CONTOUR PLOTS

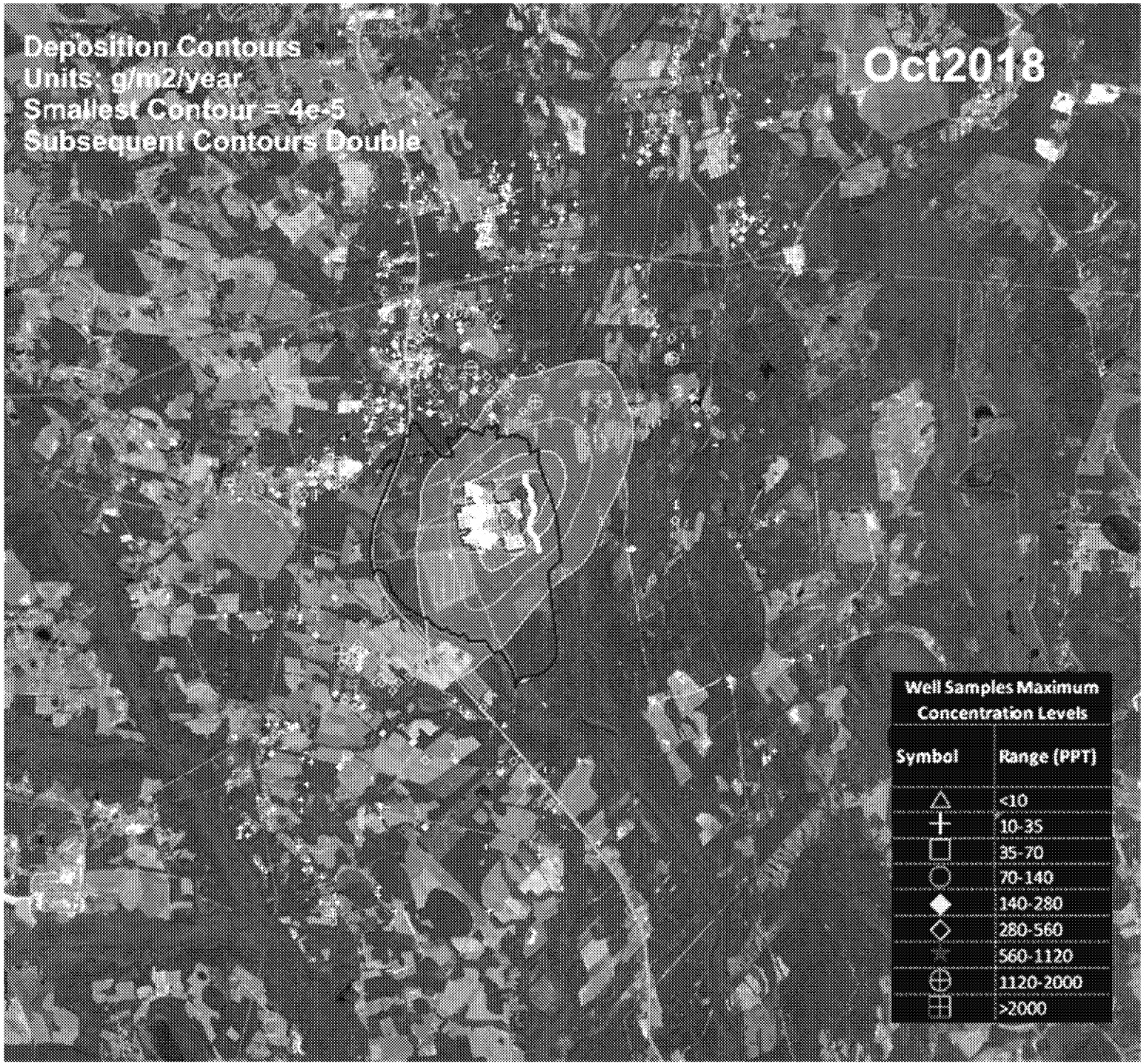
Appendix F

April 27, 2018
Project No. 0422611

Environmental Resources Management
75 Valley Stream Parkway, Suite 200
Malvern, Pennsylvania 19355
484-913-0300


Deposition Contours
Units: g/m2/year
Smallest Contour = 4e-5
Subsequent Contours Double
Base 2017
Well Samples Maximum Concentration Levels
Symbol
Range (PPT)
<10
10-35
35-70
70-140
140-280
280-560
560-1120
1120-2000
>2000


Deposition Contours
Units: g/m2/year
Smallest Contour = 4e-5
Subsequent Contours Double
May2018
Well Samples Maximum Concentration Levels
Symbol
Range (PPT)
<10
10-35
35-70
70-140
140-280
280-560
560-1120
1120-2000
>2000


Deposition Contours
Units: g/m2/year
Smallest Contour = 4e-5
Subsequent Contours Double
Oct2018
Well Samples Maximum Concentration Levels
Symbol
Range (PPT)
<10
10-35
35-70
70-140
140-280
280-560
560-1120
1120-2000
>2000

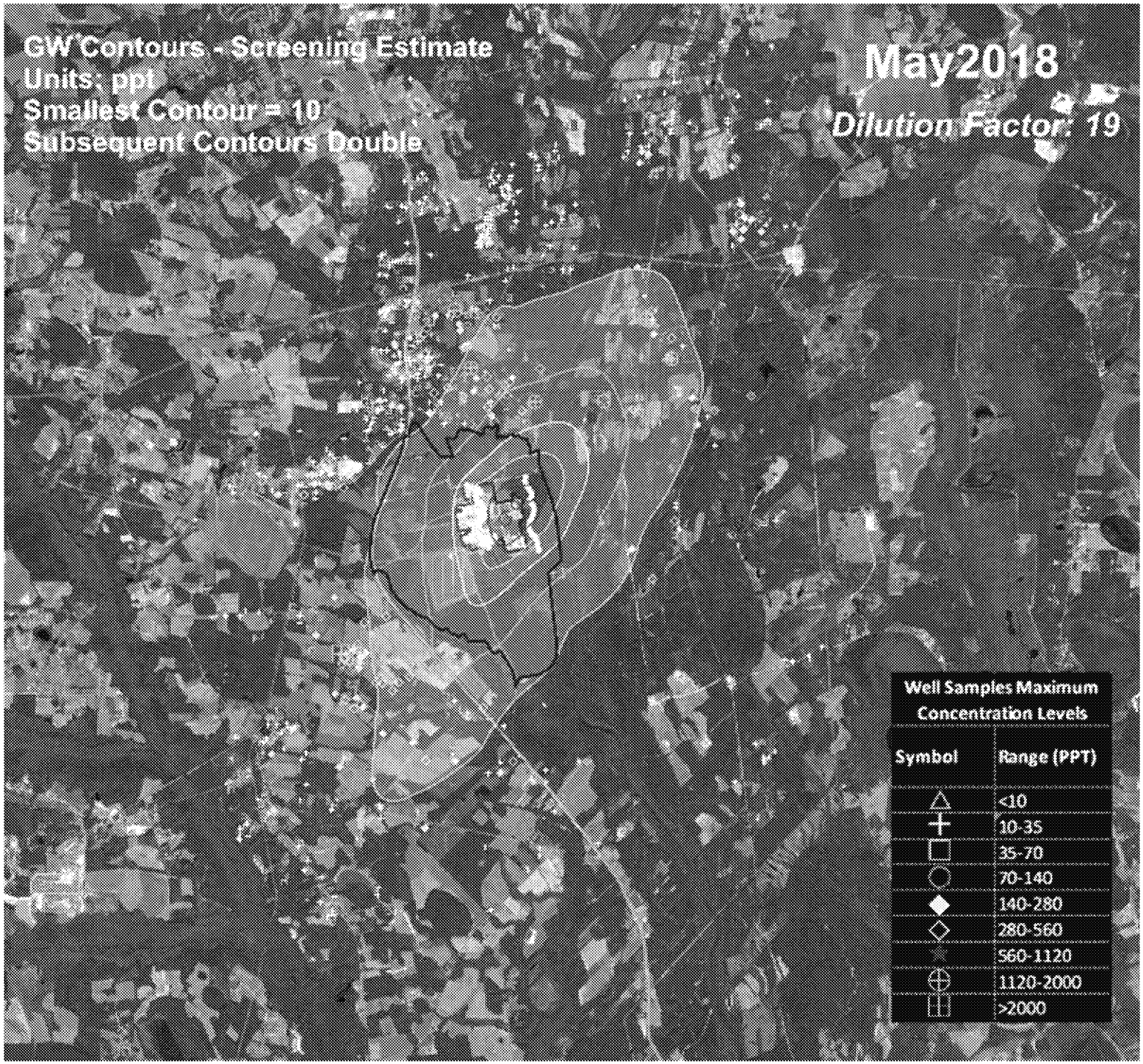

Deposition Contours
Units: g/m2/year
Smallest Contour = 4e-5
Subsequent Contours Double
2019-2020
Well Samples Maximum Concentration Levels
Symbol
Range (PPT)
<10
10-35
35-70
70-140
140-280
280-560
560-1120
1120-2000
>2000

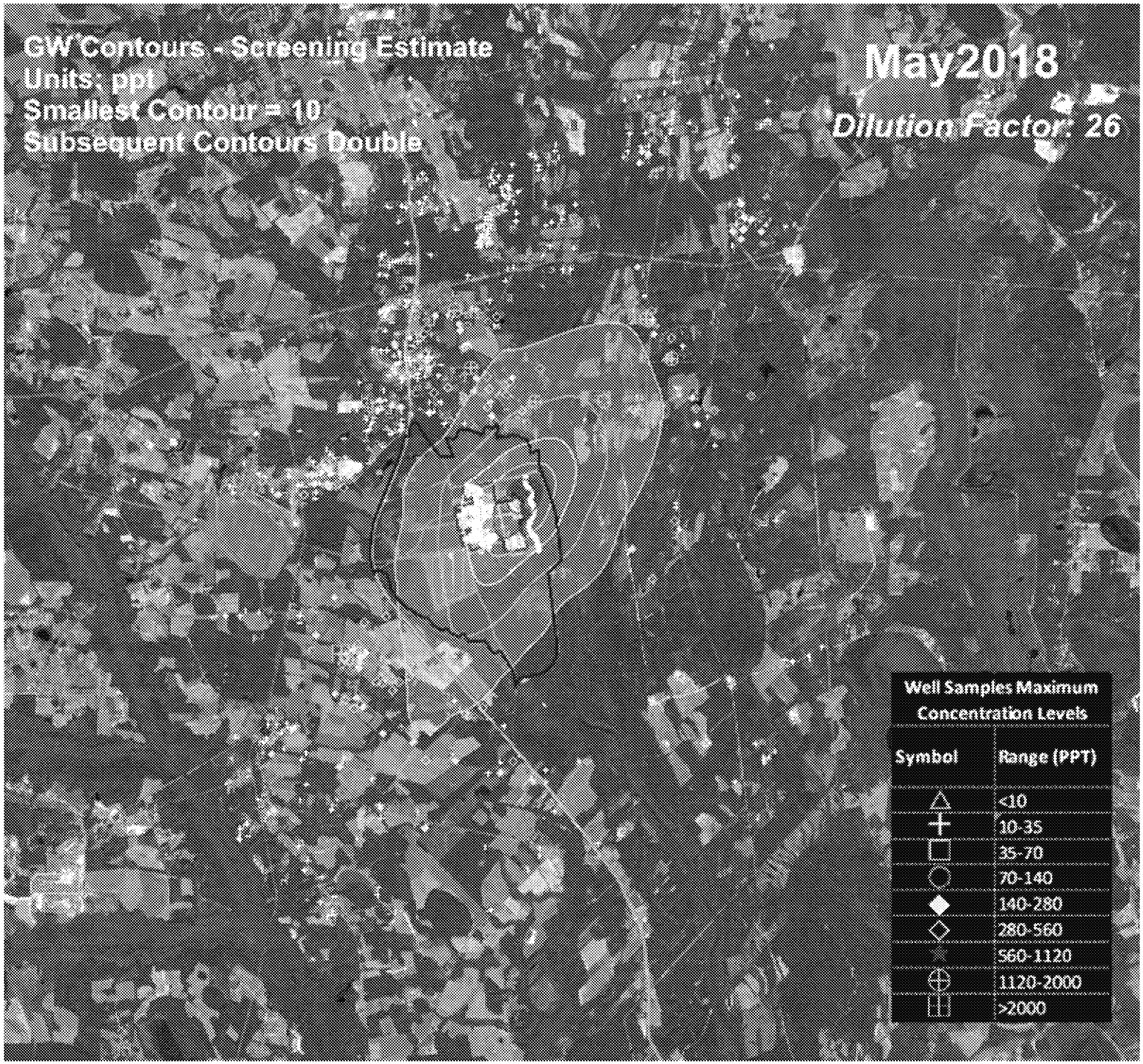
SCREENING GROUNDWATER CONCENTRATION PLOTS

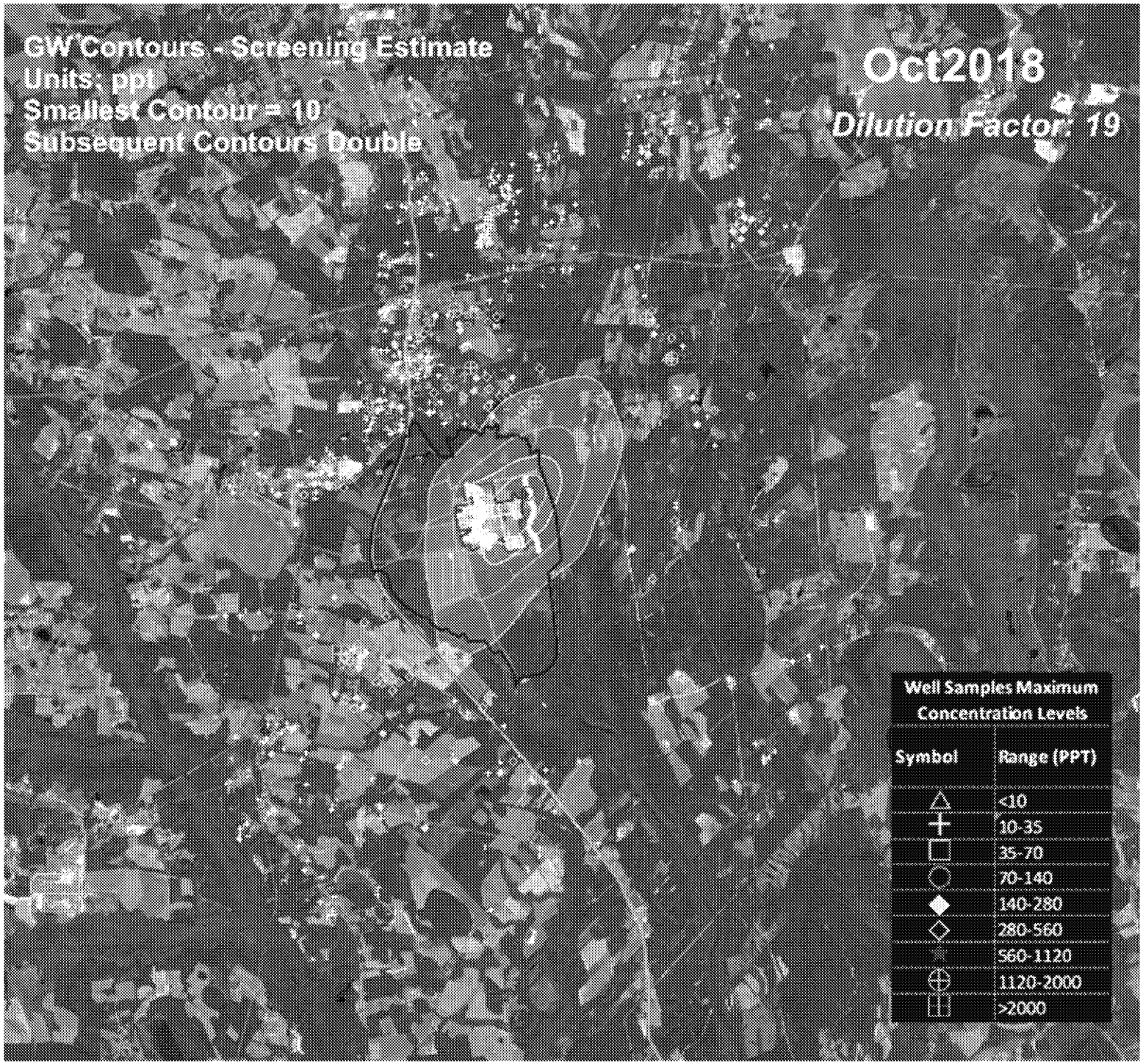
Appendix G

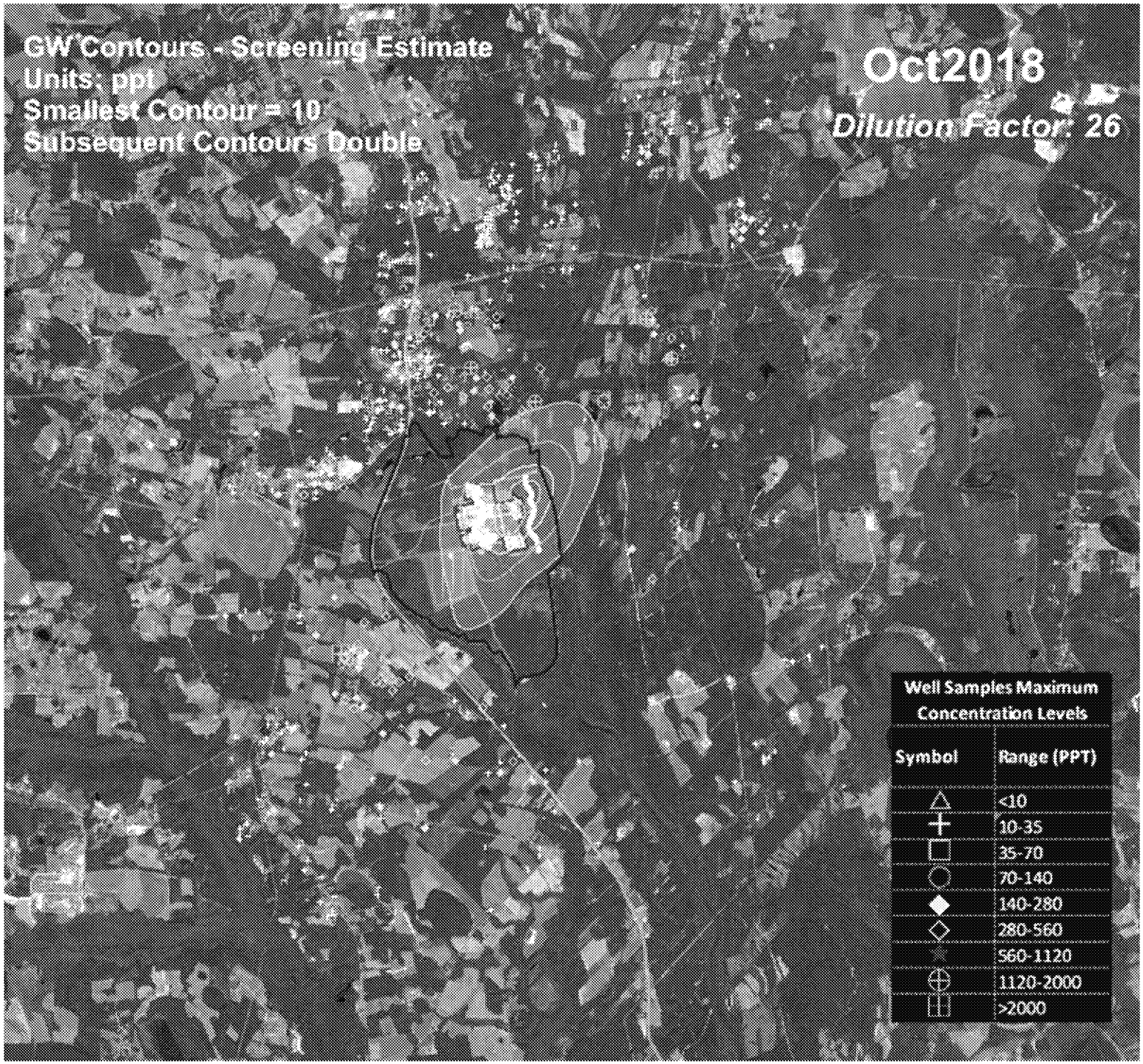
April 27, 2018
Project No. 0422611

Environmental Resources Management
75 Valley Stream Parkway, Suite 200
Malvern, Pennsylvania 19355
484-913-0300


GW Contours - Screening Estimate
Units: ppt
Smallest Contour = 10
Subsequent Contours Double
May2018
Dilution Factor: 19
Well Samples Maximum Concentration Levels
Symbol
Range (PPT)
<10
10-35
35-70
70-140
140-280
280-560
560-1120
1120-2000
>2000


GW Contours - Screening Estimate
Units: ppt
Smallest Contour = 10
Subsequent Contours Double
May2018
Dilution Factor: 26
Well Samples Maximum Concentration Levels
Symbol
Range (PPT)
<10
10-35
35-70
70-140
140-280
280-560
560-1120
1120-2000
>2000


GW Contours - Screening Estimate
Units: ppt
Smallest Contour = 10
Subsequent Contours Double
Oct2018
Dilution Factor: 19
Well Samples Maximum Concentration Levels
Symbol
Range (PPT)
<10
10-35
35-70
70-140
140-280
280-560
560-1120
1120-2000
>2000


GW Contours - Screening Estimate
Units: ppt
Smallest Contour = 10
Subsequent Contours Double
Oct2018
Dilution Factor: 26
Well Samples Maximum Concentration Levels
Symbol
Range (PPT)
<10
10-35
35-70
70-140
140-280
280-560
560-1120
1120-2000
>2000


GW Contours - Screening Estimate
Units: ppt
Smallest Contour = 10
Subsequent Contours Double
2019-2020
Dilution Factor: 19
Well Samples Maximum Concentration Levels
Symbol
Range (PPT)
<10
10-35
35-70
70-140
140-280
280-560
560-1120
1120-2000
>2000